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"THE STEREOSELECTIVITY OF THE PHOTOCHEMICAL RING EXPANSION OF SOME POLYCYCLIC CYCLOBUTANONES"

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Photochemical ring expansion in alcoholic solvents is characteristic of most cyclobutanone derivatives, but is infrequently observed in other alicyclic ketones.[1,2] The reaction itself is characterized by both remarkable stereoselectivity[3] and stereospecificity and has been mechanistically described in terms of initial α-cleavage to produce a 1,4-biradical and subsequent rebonding to a cyclic oxacarbene.[4,5] We have recently demonstrated the insufficiency of radical stability considerations in predicting cycloelimination selectivities of cyclobutanones which incorporate peripheral strain due to a 2,3-cis fusion of a strained bicyclic system.[6] We now report that this criterion is similarly unsuccessful in predicting the stereoselectivity of ring expansion in the strained, polycyclic cyclobutanones 2-7.

Degassed solutions (0.05M) of the ketones 1-7 were irradiated (3000Å) in dry methanol containing potassium carbonate (125mg/ml) and the results are shown in Table 1. We see immediately from Table 1 that low stereoselectivity in the ring expansion is a common unifying feature of this class of compounds. For 1, which was chosen as an example of a peripherally unstrained model compound, the expansion is as predicted with <5% of the other isomeric acetal produced as determined by direct glpc comparison with an authentic sample. The acetals have been characterized by analytical and spectroscopic techniques.[7] In addition, authentic samples of most of the acetals in the series 15c-20c have been synthesized from the corresponding endo-γ-lactones by reaction with diisobutylaluminum hydride in toluene at -60° and subsequent brief treatment with catalytic amounts of p-toluenesulfonic acid in methanol. These acetals could also be converted into the corresponding lactone derivatives by brief treatment with CrO_3-acetone. Similar treatment of 15a-20a produced the lactones which could be independently prepared by Baeyer-Villiger oxidation of the corresponding cyclobutanones.

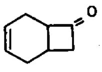
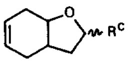
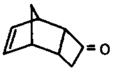
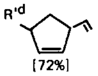
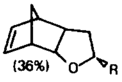
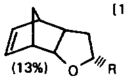
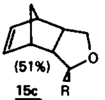
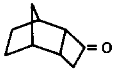
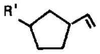
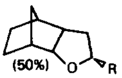
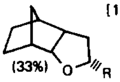
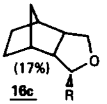
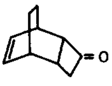
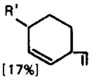
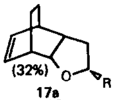
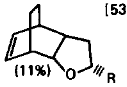
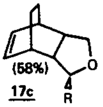
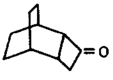
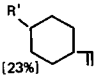
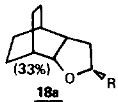
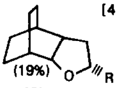
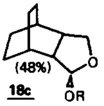
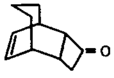
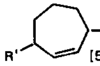
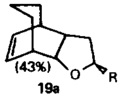
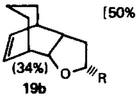
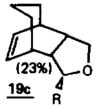
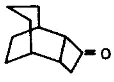
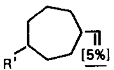
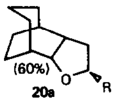
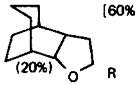
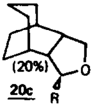
The NMR resonance of the acetal proton in the series 15c-20c appeared downfield in the region τ 5.3-5.8 either as a singlet or a narrow unresolved multiplet. The small coupling con- and insensitivity of these acetals to acid catalyzed equilibration is most consistent with an exo configuration for the methoxy group. The acetals 15b-20b were rapidly transformed to the more stable exo derivatives 15a-20a upon brief treatment with catalytic amounts of p-toluenesulfonic acid. The exclusive formation of the exo epimers 15c-20c is rationalizable on the basis of the significant steric hinderance in the tricyclic oxacarbene directing methanol attack to the least hindered size. Presumably the less stringent steric demands of the oxacarbenes are responsible for the kinetically controlled formation of the acetal epimer mixtures 15a,b-20a,b. The formation of epimeric acetals 15a-20a and 15b-20b at the same time that 15c-20c are produced as predominately a single epimers is most consistent with kinetically controlled addition of methanol to a preformed oxacarbene and less likely to arise via ring expansion directly from a methanol-ketone excited state complex.

The results in Table 1 clearly show the effect of peripheral ring strain on the competing photochemical processes. When the bicyclic moiety possesses even modest strain, the high yield cycloelimination of ketene is considerably depressed. However considerable strain is necessary (i.e., 2 and 3) for cycloelimination to the alicylic ketene, trapped as the corresponding ester in methanol, to predominate. As this pathway becomes less competitive, ring expansion to the cyclic acetals becomes the predominate reactive process.

The electron deficient nature of the carbonyl oxygen atom in the excited state,[8] coupled with the reported failure of some cyclobutanones carrying electronegative α substituents to undergo the photochemical ring expansion,[1c] suggests a possible mechanistic similarity between this photochemical reaction and the well known Baeyer Villiger ring expansion of cyclic ketones which also involves migration with retention to an electron deficient oxygen atom.[9] In this respect, simple substituted cyclobutanones show high and similar stereoselectivities for each process, i.e., predominate migration of the site of highest substitution.[10] What was needed for a more meaningful comparison are cases where either the photochemical expansion or the Baeyer-Villiger reaction is curiously unselective, a condition uniquely fulfilled by the ketones 2-7. For this reason, the reaction of 2-7 with H_2O_2-NaOH[11] was examined, and the results are reported in Table 2. Considering the extremely different reaction conditions and intermediatesm the migratory selectivity ratios of the two processes are remarkably similar, providing additional evidence that the photochemical expansion probably involves carbon migration to an electron deficient oxygen.

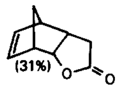
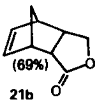
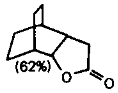
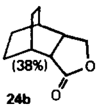
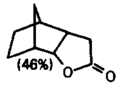
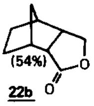
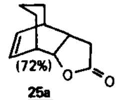
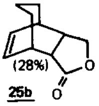
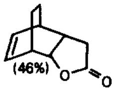
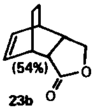
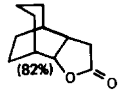
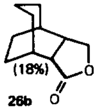
Further mechanistic studies in this area are proceeding.

Table 1.

 1	51%^{a}	—	[15%]^b  14		
 2	1%	 [72%] 8	 (36%) 15a	[10%]  (13%) 15b	 (51%) 15c
 3	2%	 [63%] 9	 (50%) 16a	[14%]  (33%) 16b	 (17%) 16c
 4	10%	 [17%] 10	 (32%) 17a	[53%]  (11%) 17b	 (58%) 17c
 5	11%	 [23%] 11	 (33%) 18a	[42%]  (19%) 18b	 (48%) 18c
 6	17%	 [5%] 12	 (43%) 19a	[50%]  (34%) 19b	 (23%) 19c
 7	20%	 [5%] 13	 (60%) 20a	[60%]  (20%) 20b	 (20%) 20c

a. Yield of olefin or diene from loss of ketene; b. [combined yield of acetals]; c. R=OMe; d. R'= CH_2CO_2Me

Table 2.

2	 (31%) 21a	 (69%) 21b	5	 (62%) 24a	 (38%) 24b
3	 (46%) 22a	 (54%) 22b	6	 (72%) 25a	 (28%) 25b
4	 (46%) 23a	 (54%) 23b	7	 (82%) 26a	 (18%) 26b

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Spectral data for these compounds are available upon request.

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